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THE DEVELOPMENT OF SCIENCE

ONE of the most significant aspects of the history of science is the comparative recency of its development, since, in its present form at least, it has been the product of the past four hundred years.

From one point of view science is indeed older than this, for the most primitive of tools, the eoliths, bear witness to observation and a crude technique. But throughout the millennia which separate the dawn of tools from modern science, men added to their store of techniques but slowly and with little change. Between the handicrafts of classic Greece or Egypt and those of Europe in the early eighteenth century, there are but few marks of distinction.[1] In so far as these handicrafts were born of observation and manipulation of materials—were, in brief, a fund of "knowing how"—they may be called a science, but a science which was meagre and almost stationary for some thousands of years.

It must not be supposed, however, that men were not curious about natural phenomena. The earlier Greek philosophers entertained many a shrewd notion which we today cherish as essentially modern. The conceptions of evolution, of the atomic structure of matter and of a heliocentric system, for example, were not unknown among the more thoughtful and inquiring. But they were destined to remain conceptions or ideas, which persisted only because of their singularity. Men were as curious and eager to know then as now, but somehow they failed to see, to understand, or to learn from what was plainly before them. Nor can we discover much more than speculation and a random collection of facts among the medieval philosophers, despite the many claims on their behalf.

Now this failure is highly significant, because, from those early days when the first rude tools were chipped from stone, there has been, so far as we can tell, no real change in man's capacities and powers. Nor, since the close of the last ice age, has the visible earth and its plant and other animal inhabitants undergone any discoverable transformation. If nature has been the same and man has gained no sudden accession of new powers, how does it come about that, so

[1] Successive explorations reveal more and more evidence of similarity between eighteenth century and classical material cultures.

late in his career, man begins the development of that habit of mind and fund of techniques and tools which we call modern science? Perhaps, if we look first at what may be called the prerequisites of science, we can find a way of answering the question, for then we can see what was lacking before modern science began.

The prerequisite conditions to a science are of two sorts: those relating to the subject-matter, and those relating to the scientists. Now it is obvious that to have a science there must be phenomena which recur.

"The repeating facts are what Poincaré has called the subject-matter of science, and naturally enough, since it is only the fact that things happen again and can be made to happen again, that makes it possible to understand how particular things happen. It is nature's repeating aspect which makes it possible to distinguish between the right way and the wrong way of doing anything, that makes it possible to learn anything by experience, that makes memory of any use and intelligence conceivable. Plant the best laboratory imaginable in a world where nothing ever happened as it has happened before; the laboratory will return to its ancestral dust before its occupants discover anything except the futility of research."[2]

Perhaps less obvious, but no less essential, man must be capable of learning from those repeating facts, not only that they are recurrent, but that there are significant relations of antecedence and consequence among them, that is, the order of recurring events. Before a science can arise, then, there must be some phenomena or events which recur and there must be some one who can learn from those recurrences that the events are generated by certain antecedents and in turn give rise to certain consequences.

It appears that nature has not altered her behavior, during man's career, but has with unfailing precision played her phenomenal drama to unseeing eyes. How then can we account for man's blindness, his inability to collaborate with his most patient and only teacher? Here we find an exceedingly interesting situation, for early man faced a world in which there were repeating facts, the self-same repetitions we witness and study today, but he was incapable of observing their repetitions. Each event came, apparently, as experience to a child—unique and discrete.

Now, we can but speculate upon these early men and how they viewed the world, but from what we know and can guess about human behavior, the situation was probably something like this.

Since causation, or better, the causal relation, is something which is never overtly given to observation, but must be patiently discovered, and, when discovered, is forever inexplicable to the naïve

[2] W. T. Bush, this JOURNAL, Vol. X, page 689.

mind,[3] it is not difficult to imagine how men came to attribute events to unseen, but potent spirits, each directing and controlling his own appropriate events. And, since events must occur in a setting which, despite the uniformity of the event, is ever changing, it is patent that these controlling spirits are capricious, variable, even as man himself, subject to occasions. It is plain, then, to the dullest that the business of man, if he would prosper in his affairs, is to propitiate these spirits, rendering unto each his proper address and offering. The assiduous cultivation of the guardian spirits, whose favor must be solicited by set form and ritual, becomes, then, the part of wisdom and the art of life, in which the greater the numbers participant, the more potent will be the spell.

Again to quote Professor Bush, "if man had not, in the earlier stages of his history, found the world full of precarious ambiguities, there is no reason to suppose that the thing called intelligence would ever have been developed. Men thought about the things it was important they should think about; food, fighting, and offspring. And very important things like these made the acquisition of mana, the control of magic, and the propitiation of deities indispensable. Thus, although primitive man inhabits a world that is sufficiently complex, he nevertheless proceeds to make it more complicated by the addition of elements that constitute his superstition."[4]

What men saw in phenomena, therefore, was the visible expression of the will of the gods; and, naturally enough, they turned in their speculations to questions of the motivation of those gods. Thus we find, apparently as a common element in every religion, a theory of the motivation of its deities, expressed in formulæ and rituals for appealing to such motives as men believe to be advantageous.

Now it is obvious, or so it would appear, that men who believe in animism and pay their devotion to spirits ruling over natural events, can not go far in developing a science. The phenomena of nature, for all their repetition, can teach man no lessons of regularity and constancy, of what we call causation, who believe in ruling spirits, capricious but placable.[5] Thus may we hazard the suggestion that

[3] The causal antecedent is almost invariably something which in appearance has no possible connection with its consequent. This is clearly shown in chemical reactions where the appearance of the reagent indicates nothing of its capacity to initiate changes. As Hume has observed, "no object ever discovers (*i.e.*, reveals) by the qualities which appear to the senses either the causes which produced it or the effects which will arise from it; nor can our reason, *unassisted by experience* [italics mine] ever draw an inference concerning real existence and matter of fact." Hume, *Inquiry*, Section IV quoted by W. T. Bush, this JOURNAL, Vol. VI, p. 395.

[4] "Emancipation of Intelligence," this JOURNAL, Vol. VIII, page 169.

[5] The presence of a problem or question of motivation is indicative, there-

the development of a science must wait upon the emancipation of intelligence from animistic beliefs and practices; only then do men come gradually to discover the repeating facts and the relations among those facts, of antecedence and consequences.[6]

II

While " the passing of the supernatural " is seemingly a prerequisite to science, it must not be supposed that animistic beliefs and practices were but obstacles to progress. For the recognition of something ulterior or anterior to phenomena, however simple and naïve were the first notions thereof, was a necessary step in the development of science. We are faced, in this development, with an evolutionary process in which validity is a matter of history and of historical setting. Just as the gill cleft, to use an analogy purely for illustration, was the prototype of the mammalian ear and may yet be found vestigially in the later form, so the notion of spirits controlling the visible events began, or perhaps continued, the habit of viewing events as part of a sequence. Moreover, the practice of magic, whereby men sought to control these spirits, inaugurated the first step in the evolution of techniques. What held animism back from further progress, apparently, was the notion that the causes (or stimuli) of a certain kind of behavior in man, were, *ipso facto,* the cause of similar behavior in all other organisms and substances; hence to produce events one should apply the same stimuli to things as to a man. This is what we call the pathetic fallacy (or one variety of it) and it is not unknown today, in various attenuated forms. It should not be overlooked, however, that this is an error about the particular kind of causal sequence, and not ignorance or a denial of causation, *in toto.*

The next stage in this evolution, metaphysics, marks a step forward, which at first sight may appear otherwise. For the older, naïve view of animism saw phenomena dynamically, as events proceeding from the will of the gods, while in metaphysics, phenomena became the illusory appearances, masking and forever hiding a changeless, uncontaminated Reality; and causation seemingly disappears. But if we pause to reflect a moment, it will be seen that the metaphysical formulation does advance the problem beyond that of animism. Instead of discrete events tossed off by capricious

fore, of an animistic tradition, with all that such a tradition implies in the way of mythical problems. This is worth recalling when we come to discuss the social sciences.

[6] " The history of human thought is a record, not so much of the progressive discovery of truth, as of our gradual emancipation from error." Inaugural Address of President Kemp Smith of Edinburgh University, Scotland.

gods, we have certain patterns which reflect a changeless reality, and, in reflecting, distort it into deceptive appearances. There is then something recurrent in the world because there is something stable and enduring, which those repeating patterns hint at; could men but find the relation between those appearances and that reality, the secret of the universe would be discovered. Men do seek that relation and seemingly find it in knowledge and ideas, which are the commerce of the soul with reality. Magic turns then from ritual to formula whereby the right idea or correct knowledge may be gained and forever secured.

Thus we have moved leagues onward, for men are no longer at the mercy of deities; they bow now to a changeless reality or absolute the knowledge of which they cherish the hope of mastering. This accomplishment waits upon the discovery of that secret relation between reality and those illusory appearances which the sensual man can not transcend, but which the soul may conquer by the formulation of the true idea or concept. The control of events is still out there, beyond the visible universe, but it is a regular or constant control which may be won over to man's purposes, not by wheedling and coaxing, but by the stern and rigorous pursuit of impersonal Truth.

Then follows a period of gradual transformation of these ideas and conceptions of metaphysics into more mechanical terms, whereby the underlying, controlling reality, as a totality, becomes a system, the forces of which produce the phenomena to be explained. The search for Truth continues, but now it is a search for the truth of causation, a knowledge of the forces of Nature which is conceived to be a vast congerie of systems, physical, chemical, and natural (*i.e.*, organic). This is still a part of the metaphysical stage, since men are chiefly concerned with supernatural systems and forces and only traffic with phenomena for the hints and clues they offer to the revelation of these systems. However, the truth men are seeking is slowly becoming more dynamic; they are asking not only *what* forces and systems of forces are in control, but *how* do those forces work and when and how much. And to answer those questions it becomes increasingly apparent that they can look only to the formerly despised sensible phenomena. The notion of a system and of forces then drops out, leaving just phenomena or events, the order of which is the sole concern of science. So we come to the present stage after these many wanderings.

We are probably still too close to the events to see how this emancipation has come about, but it begins to appear that it involved a rejection of both animism and metaphysics and the development of a further stage in our attitude and behavior toward the

world. For science sees phenomena, neither as the discrete events of animism nor as the illusory appearances of metaphysics, but rather as one of the several consequents of a sequence in which an antecedent event is followed by the event which we call sensation, perception, or observation in man and by the event which we call an effect in everything outside of man. That is to say, phenomena have a dual rôle; they initiate what are called the stimulus-response sequences in man and the causal sequences elsewhere and hence give rise to appearance and reality or to what has been called immediacy and causality.

If we could be persuaded to view man's activities just as one variety of phenomena, as we view all other phenomena, we would readily see that an event more or less simultaneously can, and does, act as antecedent to at least two consequents, among which we can distinguish the so-called effect in another event or phenomenon and in the response men make to that antecedent event. So long, however, as we are inclined to regard what is called sensation, perception, knowledge, and so on, as unique and *sui generis* (belonging to a psychic realm or mind stuff), instead of seeing them as various stages in the development of man's response to events, comparable to the stages in any other phenomena, just so long will this difficulty and confusion persist.

There is no mystery in all this, for we are constantly witnessing this plurality of causation: the falling tree not only dams the brook, but it also startles the deer feeding nearby; the blow of the hammer not only drives in the nail, but it also makes the user blink his or her eyes; the acid not only reduces the metal to a salt, but also changes its color from pale yellow to blue, and so on.

We live in a world where every event occurs in a number of sequences or releases energy in a variety of forms; these variously affect other energy complexes, since they are propagated as light or sound, pressures, and molecular motions, all of which are stimuli to which the energy complex, man, responds. Thus, there is a consequent event or release of energy in man, which we call sensation, perception, knowledge, and so on, or behavior. Concurrently in other energy-complexes, there are other consequent events which we call effects and which also release energy which stimulates man. As Hume observed, the sensible qualities of objects do not reveal anything about the other causal sequences in which those objects participate. Objects or events by themselves and singly may be the caprices of the gods or illusory appearances or anything else for which a verbal symbol can be found. But when men come to see that events are recurrent and strive to find the order of their occurrence, then science begins, for the progress of science is a con-

tinuous process of learning new ways of detecting and responding to the stimuli given off by events. Hence the importance of repeating facts.

It may be permissable, in view of the diversity of opinions upon this subject, to elaborate upon this topic. We learn, apparently, from the concurrent presentation of two or more stimuli, of which one evokes an overt response and the others do not; but after they have been presented concurrently for a number of times, the formerly indifferent stimuli alone will evoke the response which previously was appropriate only to the other.[7] Now it happens, as we have just been discussing, that events occur in sequences of antecedent and consequent, and are recurrent; moreover, both the antecedent event and consequent event stimulate man, or may be made to do so. So it has come about that these repeated sequences of events have taught men to respond to the consequent event when the antecedent appeared. To put it another way, men have learned from the recurrent sequences of events, which present their stimuli concurrently, to respond to the stimulus of the antecedent with the behavior appropriate to its consequent. And this is what we call science or intelligent behavior. Or it may be put, "intelligence is the capacity to read the signs of determinate consequences presented by the immediacy of an environment."[8]

If phenomena were not recurrent, if antecedent were not followed by consequent, it is obvious that men could never learn much of significance, for the learning of difficult lessons like causation requires many repetitions (although some varieties of hysteria may be acquired or learned from a single experience).

The evolution of science may be traced in the development of its instrumentalities for learning from the stimuli of phenomena. For until men devise instruments they can not, with their inaccurrate sense organs, respond to events with the discrimination required for the development of a science. Hence we find science progressing, *pari passu,* with the invention of its devices for detecting stimuli beyond man's range of perception, for discriminating stimuli which are, to the unaided senses, identical, for recording stimuli which are too rapid or too slow for man's refractory nerves, for measuring stimuli precisely and for translating energy releases into sensible stimuli, and so on.[9] Until these devices are at men's serv-

[7] See the writer's "Suggestion for a Theory of Learning," *Psychological Review,* March, 1923, for a fuller description of this process of conditioning reflexes in learning.

[8] W. T. Bush, "Sources of Logic," this JOURNAL, Vol. VI, p. 571.

[9] "It is no longer the outer sphere beyond which God abides that limits the range of existence but the technique of grinding lenses." Bush "Emancipation" *supra. Cf.*—the early use of pyramids for astronomical observations.

ice, they can not develop much science, *i.e.*, learn, because the stimuli of events are not available for the learning process. Incidentally it may be remarked that, in the absence of these instruments, it is not at all astonishing that men should regard appearances as deceptive and illusory: man is prone to impute his deficiencies to the shortcomings of nature. Nor is it strange that, with the progress of instrumental development for discriminating stimuli (or appearances), the notion of illusory appearances should pass away. With these instruments men have learned to respond to present events as "signs of determinate consequences," that is, to deal with antecedent and consequent, whereby they have developed a fund of techniques and tools for doing things—which is science. For a technique is a learned response or habit of behavior, which is touched off by the stimulus of an antecedent event, but which is addressed to the consequent event, that is, a uniform and reliable habit of dealing with the world of events. A tool or instrument is an addition to man's apparatus of behavior, which either improves his receptivity to stimuli or his capacity of response, as in a lens, or a kymograph, or in a lever or wedge, and so on. Machines are aggregates of instruments and tools which, by the use of cams or other timing devices and of frames, levers, and pivots for preserving a fixed range of spatial displacement, are capable of producing a train of concurrent sequences from an initial displacement—and, therefore, of bringing about a number of determinate consequences. When we speak of anything as mechanical or mechanistic, therefore, we refer to these characteristics, which are common, not only to man-made machines, but to all organisms and organized structures. The popular use of the term "mechanical" or "mechanism" in a derogatory sense is a reminiscence from prescientific days, If man were not a mechanism he could never learn anything or do anything, because learning and doing are names for the genesis and operation of certain trains or sets of sequences.[10]

This development of techniques and tools began its modern career of accelerated growth with the rise of experimental methods. So long as men despised phenomena and sought a superior sort of Truth which could be discovered only through concepts and knowledge, they naturally were content to speculate and to theorize.

When, however, they undertook the carrying over of these speculations and theories into actual behavior (*e.g.*, Galileo) and found that events rarely followed the *a priori* notions of theory, then ex-

[10] The delicacy and refinement of the human mechanism may be seen when it is noted that a single antecedent or stimulus like sound waves may set in operation the whole organism which is a myriad of sequences, all coördinated and synchronized. *Cf.* the electrical spark in an automobile.

periment was born, or at least became respectable and dignified, and from experimentation came techniques and tools. That is to say, men learned from experiments how to behave toward the sequence of events, as we have previously discussed, and this learned behavior we call techniques and tools. It is obvious that until men did experiment under controlled conditions (exclusion of irrelevant sequences and so on) they could not develop a reliable and uniform way of dealing with the world, and that these experiments are largely instrumental manipulation of sequences and their stimuli.[11]

The progress of science then is the learning process writ large, for the rat in the maze and the scientist in his laboratory are both engaged in the trial and error process of learning how to behave in new situations, wherein the order of events is the crucial element to both. And as in all learning, progress is slow at first and then more and more rapid, save for occasional plateaus, so, in the history of science, we see men learning more and more rapidly and from more and more difficult situations, as time goes on. Perhaps the most difficult lesson science has had to learn is to distinguish necessary from fortuitous (*i.e.*, extraneous) sequences (*cf. post hoc propter hoc*) and sequence from concomitance.

It is interesting here to consider the rôle which mathematics may have played in preparing men for science. Being less concerned with animistic affairs, since it was not addressed to actual appearances and phenomena, it taught men to see and note repetitions, quantity, and the sequences of time and space, long before these were generally noted in phenomena.[12]

It so happens that nature is an aggregate of point events (as the physicists phrase it), that is to say, a multitude of spatial and temporal sequences. Since time and space are dimensions in which energy moves, these sequences are quantitive and hence we have the three classes of problems with which science deals: one, the problem of temporal order or sequence, which we also call function or behavior; two, the problem of spatial order or sequence, which is also known as structure or organization; and three, the problem of quan-

[11] The aim of experimental work, it appears, is to discover the sequence of events (temporal and spatial and the quantities of energy involved) which leads to determinate consequences; this necessitates, *inter alia*, the exclusion of fortuitous concomitance and the disclosure of the prior stages of the sequence under study in order to reveal any hysteresis or persistence of prior activities or structural changes, initiated by earlier antecedents as, *e.g.*, temperature or heat in chemical reactions or habits in man.

[12] This does not mean that mathematics was not subservient to idealism and supernaturalism (as it still frequently is), but that mathematics and science have progressed together, since mathematics is a tool for handling the data of experiments and for revealing situations where experiments may be tried (*e.g.*, mathematical physics).

tity. Function, structure, and quantity, then, are the three basic aspects of all phenomena, which can not be handled separately, since an alteration in any one involves an alteration in the other two. Frequently men discover at first only one of these sequences and, after patiently studying that, are forced to halt until the others are disclosed, for until men have learned all three (or at least something from all three) they can not develop a technique or a science, since a technique, as a reliable and uniform way of dealing with phenomena, must be addressed to these three aspects of phenomena.

When Descartes asserted that extension was essential to existence, he was at once insisting upon the importance to a science of appearances and the necessity of discovering spatial order. Today science has learned that there can be no behavior or function without an organization or structure, and *vice versa,* and that both exhibit a definite quantity in every sequence. It has also become clear that every phenomenon is one of a long chain of sequences and hence to discover its nature we must look to its origin, and that to analyze anything we must trace its genesis.[13] Thus we find the most advanced science, physics, studying the point-event in an effort to disclose, not only the temporal and spatial sequences in their most fundamental forms, but the genesis of such basic sequences as well.[14] This situation in physics which is addressed solely to the disclosure of sequences and quantity may be contrasted with the situation in psychology which is concerned with explanations of *why* men behave as they do, how the ego or knower or mind stuff can have any knowledge of " reality " and sundry other problems raised by its various conceptions of psychic entities and of non-structural functions, practically none of which are concerned with the discovery of sequences. Such a contrast reveals the opposite ends or wings of the movement of intelligence.

The test of a problem is whether it involves learning how to deal with a phenomenon, by discovering the sequences and the quantities thereof in which it occurs, or whether it is an enterprise in defending old habits and beliefs or reconciling antithetical concepts. Problems of the latter variety are never solved, except by showing that they were generated by unreal assumptions. The scientific method is simply to approach situations prepared to learn therefrom, and its rarity may be due to the difficulty of changing our habits and attitudes toward the world, which continued learning demands.

[13] See John Dewey, *Essays in Experimental Logic,* p. 93.

[14] *Cf.* "a knowledge of the whole history of a single particle is shown to be involved in a complete knowledge of its state at any moment." D. Langhorne-Thornton, "The Einstein Theory of Relativity," *Science Progress,* April, 1922.

Among the lessons which science has learned is to employ the language habit of men as a means of directing others how to find, observe, and to manipulate events and to use the techniques and instruments it has developed. These directions are given in what we call laws or generalizations which are continually being modified as men learn better techniques and discover new sequences. And since language or terms are used to direct others how to deal with events, it is necessary to exercise great care and precision in the use of those terms, so that the sequences of the events discussed will be retained in the terms thus employed. When language is so used we speak of it as being logical. It will be seen, therefore, that logic awaits upon science to reveal sequences and can not of its own motion discover events, although it may suggest where and how sequences should be sought.

To those who are but slightly acquainted with scientific work and who come to science through these verbal directions, it may appear that science is organized knowledge or true propositions and so on, and that the business of science is to formulate laws and generalizations, using experiments (as a necessary evil) solely to verify hypotheses and theories, which, being verified, become Truth. They see science as progressive stages in the elucidation of true knowledge and they rate formulæ and symbols as a higher "reality" than the events to which they refer. This is undoubtedly a part of the intellectual, rationalist tradition, deriving from metaphysics and animism, as suggested earlier, which looks to dialectics and Aristotelian logic as instruments of discovery and of accomplishment, not unlike the ancient faith in spells and incantations to placate and coerce the deities.

The "passing of the supernatural," which could only be approached dialectically (because it was never anything but a formula for an attitude toward the world), is bringing about the gradual decay of the rational tradition and the intellectual method; both are becoming obsolete, as science develops new and better techniques, for want of which they have so long prevailed among men.[15] In emphasizing, if not exclusively describing, science as organized or integrated behavior, techniques, habits of manipulating, and so on, all of which are learned responses, we are but calling attention to

[15] I am indebted to Professor John Dewey for the foregoing essentially instrumental position. See his *Essays in Experimental Logic*, especially the chapters on "Thought and its Subject Matter," "Data and Meanings," "Objects of Thought," and "Stages of Logical Thought." Also to Professor W. T. Bush, to whom references have already been made, especially his "Emancipation of Intelligence." These views suggest that some day we may have a science of sciences, a technique for establishing and evoking scientific habits in man, which may in time displace that quaint custom we call education.

the most significant aspects of science, significant, that is, for philosophy and nascent sciences. For this behavior interpretation disposes of (some will surely say, evades) questions of what and where is knowledge, and how can we know things, together with all the other queries and perplexities of epistemology. It indicates that all we "know" or can "know" is how to behave or do something (including the fabrication of verbal symbols for use as responses or as stimuli, for others), and that "knowledge" and science are located, not in some problematic sphere of existence (mental, ideal, spiritual and so on), but in the apparatus of behavior, nerves, muscles, glands, and the rest, where they function as learned responses or habits.[16]

Moreover, it recognizes science as something in process of becoming, like everything else in nature; that is, it provides a clue to the natural history of intelligence and dispels much of the mystery and apparent singularity that has clung to that form of behavior. For it reveals science, or increasingly intelligent behavior, as something quite congruous to an evolutionary world, where, apparently, chemical elements, organized forms, both animate and inanimate, indeed, everything that goes to make up what we call nature, have gradually developed their appropriate patterns of behavior, or what we call phenomena. Is this not what evolution means? Nor is it perhaps irrelevant to note that the diversity of these patterns of behavior (nature's habits) and their rate of secular change (evolution) are more or less correlated with increasing organization or morphological complexity; so that at one end of an imaginary scale we may place the electrons, with a single response to only one stimulus, and at the other, man with an indefinite number of responses to all stimuli. And if we are moved to generalized theories or cosmologies, can we do better than interpret nature, in her infinite variety, as diverse complexes of energy, with varying degrees of stability or fixation of behavior or energy release, which is elicited by appropriate stimuli or antecedents, some learned in

[16] It will be noted that, in recognizing what we call knowledge as a behavior response which men give to phenomena, and therefore as one consequence of an antecedent event (or as part of a causal sequence), many of the problems of epistemology involved in the copy theory, the representation theory, and other theories of knowledge, may be disposed of, by showing that they are generated by assumptions and conceptions which do not apply. Incidentally, the questions raised by Professor Lovejoy in "Pragmatism and the New Realism," this JOURNAL, Vol. XIX, p. 5, (January, 1922,) also find their answer in the above. See the writer's "Locus of Experience," this JOURNAL, Vol. XX, p. 327, (June, 1923.) Also it may be pointed out that scientists are rarely troubled by theories of epistemology, much to the distress of many philosophers who are unable to accept scientific achievements until they have explained how science can know things.

geological past and others but today.[17] Then man and his behavior, including his science, may be seen in a better perspective, as one of the numerous kinds of energy complexes which have arisen in the course of evolution, a complex unique perhaps in its mode of release or behavior, in that it continues to change or learn new habits, with accumulating experience. And some day perhaps this unique energy complex may learn the supreme technique whereby it will compel all other energy complexes to learn to behave as its developing needs and intelligence require, for today, on the frontier of science, men are trying to elicit responses from seemingly inert complexes and to find new ways of initiating sequences (this is what the physicists are doing in bombarding helium atoms with X-rays and the chemists in the fabrication of new substances).

Science has been at once the creation of new techniques and tools and the discrediting of magic and its associated beliefs, but the two processes are not synchronized, for frequently men have developed a technique without relinquishing the edifice of ancient beliefs which it had ruined. Lavôsier, for example, who is credited with the discovery of combustion, nevertheless refused to give up the older notion of heat as a substance. The discoverer of oxygen, Priestly, never saw how his own efforts had made untenable many of his cherished beliefs. And Cuvier was a rabid opponent of those who, like Lamarck and the early paleontologists, questioned the doctrine of special creation.

On the other hand, Francis Bacon and Descartes, to name only two of the more prominent, attacked old ideas and beliefs which they saw impeding the path of scientific discovery, although they did not, especially Bacon, contribute to the fund of techniques. Their skeptical questioning of ideas and concepts were directly productive in the work of their successors who, freed from some of the older notions, could approach phenomena better prepared to learn.

But this dual process of emancipation and of discovery of techniques is a cumulative affair. It is as if man were held by innumerable thongs, closely intertwined, so that the picking of one knot

[17] It may be appropriate here to suggest that since the term "causation" is so loaded with animistic notions and implies so much more than the empirically discovered order of events, it might be well to use the term "stimulus and response," instead of "cause and effect." As suggested earlier, a stimulus is something which releases energy from a complex (organism, chemical element and so on) which, either in the long process of evolution or in the short period of individual experience, has, so to speak, "learned" to discharge to that stimulus. Phenomena then might be distinguished, *inter alia*, according to the degree of hysteresis they exhibited (*i.e.*, persistence of immediately prior experience, such as habits in men's behavior or the variation of a chemical reaction with temperature changes, or the practical immunity to experience as in inert gases, helium, and so on).

made possible the loosening of numerous fetters; and with the freedom thus gained, the labor of further emancipation was made easier. Thus it would appear that at some not distant day man would at last be entirely free from the fettering heritage of the past, but, unfortunately, even in science, we find that the heresy of today becomes the orthodoxy of tomorrow and must in its turn be thrown aside.

While the genesis of science may be traced to the discovery of the repeating facts and the learning of patterns of behavior therefrom, it must be remembered that science is a developing body of habits or techniques. In this development, one generation patiently works out a bit of technique or improves upon an existing technique and comes to a halt in its labors, with a concept or attitude toward that which has not been brought under technical control. The next generation starts with the techniques and the concepts or attitudes taught by the earlier generation and, after vainly striving to make its contribution of techniques by applying those attitudes to phenomena, it finally throws them aside and responds to the phenomena as directly as it can, whereby its technical contribution is achieved. That is to say, the movements of a science begin and end with concepts, between which there is active experimentation. This is nothing more or less than life itself, where youth for the nonce adopts the fixed habits of age, only to renounce them for the privilege of building up its own fixed habits and so on, world without end.

III

One writes history, as a recent paper has suggested, because of one's interest in the future [18] and this sketch of scientific history is oriented to the future of the social sciences, economics, politics or political science, sociology, psychology, and history. Judging from this history, the social sciences may be expected to follow roughly the same evolution that we have traced above. How this will probably come about may be briefly sketched as follows:

At the present time the social sciences are still in the grip of an animistic tradition which is revealed by the conceptions and problems occupying their attention. Central to social science is the conception of human autonomy or volition and the problem of motivation which this conception generates (see note No. 5.). Hence we find the several branches of social science engaged in describing men's motives and constructing explanations of how they produce his behavior, specifically as in economics, politics, and sociology, or generally, as in psychology and in history. With changing fashions

[18] J. W. Swain, "What is History?" this JOURNAL, Vol. XX, pp. 281, 312, 337.

in the theory of motivation, social science has been modified from time to time.

An equally important question in social science is that concerning the obvious regularity and interrelation of social events, which is approached through the conception of an economic or social system, sovereignty, a group mind or social organism, and the like, the operation of which, manifested in various social forces, accounts for this regularity and interrelation.

It is fairly obvious that the conception of autonomy must be accompanied by the conceptions of system and so on, in order to take care of the two features of social life, individual variability and social uniformity. And it is not difficult to discover, in these two basic conceptions, reminiscences of the animistic and metaphysical traditions. For human autonomy, volition, or rationality is an attenuated form of the soul and the various economic, political, and social systems with their forces are survivors of the "Universe," " the Absolute," and other conceptions of the totality of reality, as we have previously seen. Quite in the traditional manner, therefore, we find the economic, political, and sociological branches of social science engaged upon the problem of reconciling these antithetical concepts, or of revealing the system of forces which produce events, while psychology, which supplies the necessary theories of motivation, is occupied in bringing into harmony the conceptions of a psychic knower or doer and a physical world of phenomena.[19] History, borrowing from the others, interprets the past in terms of contemporary political, economic and sociological theories, in the service of polemics or apologetics (see reference to Swain in Note No. 18).

In these troubled waters it may indeed seem vain to fish for promise of scientific development. And yet the case is not so hopeless as may appear from the foregoing account. Taking our cue from the history of science, we should seek for repeating facts or recurring phenomena, the discovery of which will at once dispel the animistic and metaphysical traditions and provide an opportunity for a social science to learn. In this quest we have not far to look, since, as we have seen, human behavior is being ever more clearly revealed as a sequence of antecedent and consequent, or as we more familiarly put it, situation-stimulus and response. So soon as we come to see behavior as part of a sequence, the conception of autonomy and volition and the metaphysical notions of social systems

[19] *Cf.* E. A. Bott, "Criticism and Ways of Inquiry," this JOURNAL, Vol. XX, (May 10, 1923,) pp. 260 and 261 who has characterized this psychological procedure as the " split field method." In the following paragraphs will be found a tentative answer to some of Professor Bott's queries.

and forces are rendered superfluous, since the problem may be approached quite simply as one of sequence in individual and group behavior.

As suggested above, the behavior sequence is becoming familiar under the terms " stimulus " and " response." Unfortunately, however, these terms are not infrequently employed or understood in the older sense of cause and effect, and much good effort is being spent in the vain attempt to prove, and the superfluous intention to disprove, that the response is " caused " by the stimulus-situation. It is fairly clear that in the behavior sequence, the antecedent stimulus plays the same rôle as in any other sequence: it is an energy release which acts upon the energy complex, man, to release in him the energy of response; the form or pattern of the response is that developed in prior experience when the response was learned as a consequent to that stimulus. These learned responses are usually known as habits, so that we may describe the problem of behavior as the sequence of antecedent stimulus, habit, or prior experience and consequent response.

It happens that the young are carefully guided by their elders, so that, in the main, they learn only those habits which this controlled experience provides. In general these habits may be described as (*a*) avoiding reactions which are established by the parents' repeated frustration or punishment of attempted response to stimuli, and (*b*) institutional habits which are learned as the only approved or group-sanctioned modes of response to these forbidden stimuli. That is to say, under the tutelage of the guardians of our youth, we learn certain habits which are essentially taboos and taboo practices, although we are accustomed to describe these taboo habits toward things as private property and toward persons as liberty, chastity, and so on, while the taboo practices of contract and sale, the " price systems," marriage, divorce, and the like are known as social institutions.

It is obvious that each individual will learn these taboos and the use of taboo practices in accordance with his individual experience and inherited capacity to learn therefrom, so that the behavior of adults will exhibit a fairly wide range of individual variation within the taboo and the institutional patterns. This individual variability gives rise to the appearance of autonomy and volition (and the notion of inner motives), while the constancy and uniformity of the aggregate of this learned behavior in a group suggests an " organized " society. Moreover, since these taboo practices or institutions are the only approved patterns of behavior toward other persons, (through whom the forbidden stimuli must be approached), the aggregate of institutional behavior of one portion of a group acts as a

stimulus to another portion of the group and so on, as if there were a social system, social forces, and the like.

We may forecast, then, with a reasonable degree of expectancy, the development of a social science from the study of these habitual behavior sequences. As the writer has elsewhere suggested,[20] a division of labor in social science, following much the lines of traditional interest, may be anticipated. Psychology or physiology will undertake the study of the learning process or habit formation in the individual, as a process of modification of structure and function (spatial and temporal sequences), under the impact of experience. History, as the analytic or genetic branch of social science, will trace the development of these taboos and taboo practices as they have evolved through the suppression and elaboration of more primitive patterns of behavior.

Economics, political science, and sociology will be devoted to a study of the several institutional patterns or taboo practices employed in the response to forbidden stimuli. Thus economics will be addressed to the practices of contract, sale, and the use of money and credit (the price system), as a response to the stimuli of things and persons. Political science will look to those practices which we sum up under the term, the "state," involving the making and enforcing of law (or taboos and taboo practices), the selection of group surrogates and so on, as another mode of response to the stimuli of things and persons. Sociology will cultivate the study of marriage, divorce, and other institutional practices, such as education, and the like, whereby we respond particularly to persons.[21]

In many respects social science will face a more difficult task than the other sciences, since these behavior sequences, unlike other recurring events, are not so uniformly continuous, specific, and determinate, or temporally, spatially, and quantitatively fixed as in other phenomena. That is to say, individual habits do not become fixed until maturity and institutions, in consequence, change from generation to generation (the mode gradually moving toward the "left") while the sequences studied by the other sciences are fairly continuous, and unbroken for long geological epochs. Moreover, the sequences studied by the other sciences are fairly specific

[20] "The Emancipation of Economics," to appear in a forthcoming number of the *American Economic Review*.

[21] The trend toward a recognition of the problem of social science as that of behavior is indicated in a number of quarters of which only a few may here be noted: Clark Wissler, *Man and Culture*, especially Chapter XII; J. H. Robinson, *New History;* Teggart, *Processes of History;* Oppenheimer, *The State;* Veblen, *Theory of Business Enterprise;* Mitchell, *Business Cycles;* Ogburn, *Social Change;* Watson, *Psychology from the Standpoint of a Behaviorist*, etc., etc.

in that only one or two antecedents (so far as we now have learned) will generate a given consequent; but in man's behavior any stimulus may become the antecedent to a habit-response. This is beautifully illustrated by the habit of language. Again, the other sequences are determinate, a given quantity of antecedent generating a given quantity of consequence, but in the human behavior sequences we may find certain stimuli evoking a large, a small, or no response from several individuals in accordance to their experience. Now this, as suggested earlier (see note No. 17), points to an ascending scale of phenomena, arranged according to the rapidity of secular change or evolution in functions, or the degree of hysteresis (structural change) possible to individuals, or the capacity or ability to learn from a given number of experiences, to put it in human terms (these are merely various ways of looking at the same phenomena which is one of change in the fixity of antecedence and consequence, or temporal, spatial, and quantitative order). Nor is it perhaps irrelevant to remark here upon the order of development of the sciences, with astronomy at the beginning, closely followed by physics and chemistry and, bringing up the rear, the social sciences—an order of phenomena which corresponds to the scale just described. This order of development in science, it may also be noted, is not unrelated to the learning process, by which we have described the development of science, wherein we learn first from the most continuous, specific, and determinate sequences (such as we find in astronomy) and then, slowly, from the less and less regularly recurrent sequences until, as now, we face the most difficult lesson of all in men's behavior.[22]

While the task of the social scientist is more difficult in many ways than that of the other scientists, yet he has the advantage of other achievements to guide and assist him. It will be easier than may here appear, however, since man's habitual activity is almost always associated with a ritual or ceremony involving symbols and records, such as in property, money, marriage, group coercion, or politics, and so on. This means that the sequences can be traced by the records and symbols accompanying them, just as photographic records reveal activities not visible to the eye or a zinc plate discloses the impact of alpha particles. Much of the present confusion in the social sciences arises, seemingly, from an inability to deal with these various symbols and ceremonies which men have elab-

[22] *Cf.* the learning process in an infant who learns first to deal with spatial events, then temporal and finally with quantity. This is congruous with the writer's suggested theory of learning from the repetition of concurrent stimuli, which establish conditioned reflexes, since the more uniform and unvarying the sequence the more easily the conditioning occurs, except for certain forms of hysteria.

orated with their habits. Money and credit, for example, operate as vehicles both of stimuli and of responses, in the habits associated with economic affairs, but they are regarded more or less as independent events, having their own order or sequence apart from men's behavior. As soon as it is seen that these various symbols are part of the taboo practices of contract and sales and that they occur only as they function in a behavior sequence the problems associated with their use will be quickly resolved.[23]

If, as suggested above, the social sciences develop by learning from the repeating sequences of men's behavior, they will achieve a scientific status by establishing techniques for initiating and directing sequences which lead to determinate consequences. This means that a social science will truly begin with the discovery of a technique for directing, and controlling, as we say, men's behavior, that is, establishing the habits necessary to a *social* life and then keeping them in continuous and exclusive operation. But it is obvious that to develop such a technique there must be more than observation and a statistical manipulation of institutional records (mass habits); for, although these may help to develop a certain amount of shrewd and fortuitous effectiveness in affairs (as we see in business, political parties, and so on), the very fact of studying the aggregate of activities renders discovery of sequences highly improbable. The order of behavior events is confused by the plurality of "causation," by the cancelling out of conflicting activities, and by the multiplicity of irrelevant sequences. In this situation social science, as with all other sciences, will turn to experiment on individual and group behavior, where sequences can be isolated and techniques developed.[24]

In the development of these experiments there will necessarily be a long period of fumbling around and of more or less sterile research, as in psychology, where we are still repeating the same line of experiments that were devised forty or fifty years ago. Here there will be needed a fairly rigorous testing of problems, since sterile research is usually the result of following mythical problems. It should be fairly obvious that to conduct experimental studies on most of the present "problems" of social science would be a rather

[23] *Cf.* the writer's papers on "Long Term Price Trends," *Journal of American Statistical Association*, September, 1923, and on "Business Cycles," *Quarterly Journal of Economics*, August, 1923, wherein an attempt to use this type of analysis has been made on two current economic problems.

[24] It is indicative of the present temper of social scientists to note that they frequently declare that experimental work is impossible for them, because, forsooth, they can not bring all of society under their control. By this criterion all experiments would be stopped; but it will become increasingly apparent that experimental science deals with samples of the phenomena to be investigated and not all phenomena.

barren enterprise, for these problems are not capable of resolution in techniques. (See earlier reference to test of valid problems.)[25]

There are already under way certain tentative endeavors in the way of experiment upon habit formation, for example, new varieties of schools. Advertising agencies are conducting (more or less unwittingly) numerous experiments on group behavior, habit breaking, and the like, and in industrial organizations there have been many highly instructive trials made on integration of group habits. All these are part of the apparatus of education for social life, just as much as the formal schools. And we may expect that when the techniques of social science are discovered they will replace these present fumbling efforts, which we are forced to use in establishing the habits of group life. Since we are possessed of no techniques for accomplishing the more desirable social conditions, it is not strange that we have achieved but a partial success in that direction. Incidentally, it may be noted that probably the most urgent need of a social science today is a technique of habit breaking, since the anachronisms in habits is not the least of our social difficulties.

In all this the philosophers, in their traditional rôle, or as psychologists, must play a leading part. For the social sciences are the legatees of a number of philosophical traditions (animism, metaphysics, and dependence upon dialectical instruments and so on) from which only the philosophers can deliver them. Nor is this asking from philosophy more than we have learned to expect, since it has ever been philosophy's greatest contribution, to emancipate men from error.[26] From Plato down, the enduring work of philosophy has been the efforts not to "reveal nature's secret's," for these attempts have all paled in the light of scientific progress, but rather to strike off man's fetters and disclose his self-generated obstacles to learning from events. Today especially this task calls

[25] Thus it is that "the progress of science in any branch continually brings with it a realization that problems in their previous form of statement are insoluble because put in terms of unreal conditions; because the real conditions have been mixed up with artifacts or misconstructions. Every science is continually learning that its supposed solutions are only apparent because the 'solution' solves, not the actual problem, but one which has been made up." John Dewey, *Essays in Experimental Logic*, p. 101. Until the rise of the experimental methods (*i.e.*, carrying our attitudes or concepts into overt behavior), men were at the mercy of whatever set of verbal symbols tradition and expediency supplied. See also Bush, "Emancipation of Intelligence," this JOURNAL, Vol. VIII, page 176, for illuminating discussion of the varieties of problems and methods of testing their validity.

[26] Professor Dewey is not unmindful of this obligation and opportunity, as witness his efforts to promote a social science in *Reconstruction in Philosophy*, *Human Nature and Conduct*, and his books on educational subjects.

for the best efforts of philosophers, since the future well-being of man is dependent upon the achievement of a social science or social technique. Moreover, with the not distant obsolescence of many of philosophy's ancient interests, epistemology, cosmology, and other kindred topics, philosophers will soon be left with no other task than that of critic of men's beliefs and conceptions.

This then is my excuse for rehearsing again the well-known story of scientific development and for presenting these numerous borrowings from others; to enlist, if possible, the efforts of philosophy in what may possibly be the last great enterprise of scientific pioneering—the opening up of a social science.

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BOOK REVIEWS

La Pensée d'Ernst Mach. ROBERT BOUVIER. Paris: Librairie au Vélin d'Or. 1923. Pp. xiv + 370.

This book is a serviceable and desirable account of the philosophical ideas of Mach. It is in two parts: first, an exposition of Mach's intellectual development, an "intellectual biography," comprising nearly two-thirds of the book; second, a critical examination of certain aspects of Mach's thought.

The "intellectual biography" shows Mach first as a youthful reader of Kant. He then becomes interested in psycho-physics and the physiology of sensation. The next, and perhaps the main interest of his life, was the development of physics with special reference to the fundamental principles of the science. This interest, however, keeps him in touch with problems of sensation, on the one hand, and, on the other, leads to a generalization of scientific method, and the theory of knowledge. From this arises a renewed study of sensation and a study of psychological method.

The problems to which the author devotes critical attention are those of explanation in psychology, the philosophy of the sciences, and phenomenalism. As to psychology, he points out the excessive preference for the mechanistic viewpoint that leads Mach to neglect to study adequately affective life, personality, consciousness, memory, habit, attention, and will. In the philosophy of sciences the author believes Mach has finally defined scientific method, but is, at times, in confusion from defining laws sometimes as "comprehensive descriptions" and again as rules to guide our mental activities in reconstructing phenomena, a mixture of empiricism and pragmatism uncritically developed. The third point of criticism, phenomenalism, is developed in the form of a dialogue between a follower of Mach,

an independent truth-seeker, and a sophist in which the current criticisms of phenomenalism, as well as the doctrine itself, are evaluated.

A useful bibliography of Mach's writings and one of books concerning Mach, is appended.

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Chance and Error. MARSH HOPKINS. London: Kegan Paul, Trench, Trubner & Co., Ltd. New York: E. P. Dutton & Co. 1923. Pp. vii + 223.

This little book consists in part in problems which are treated exhaustively in the better type of college algebras, and in part in philosophic lucubrations which the reviewer can not presume to discuss, as they are developed in no known terminology, and as the author has no glimmering of an idea as to the proper nature and function of a definition. Definition 14, for example, reads: "An element of anything is very small when its magnitude may be disregarded"; definition 19 is "The Natural chance of anything is the true chance when a unit is a very small element of the thing."

In the introduction, the author says, "The subject took such a hold of me that for a number of years I constantly worked at it in my sleep." The book bears much evidence of having been written before he had fully awaked.

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JOURNALS AND NEW BOOKS

SCIENTIA. Vol. XXXIV, N. CXL–12. What is the Place of Postulate Systems in the further Progress of Thought? *R. D. Carmichael.* La symétrie dans la nature: *F. M. Jaeger.* Origine des races domestiques des plantes et des animaux: *M. I. Newbigin.* La politica inglese nel Mediterraneo durante i due ultimi secoli: *P. Silva.*

THE PHILOSOPHICAL REVIEW. Vol. XXXII, 6. On Bosanquet's 'Idealism': *R. F. A. Hoernlé.* Bosanquet and the Future of Logic: *R. C. Lodge.* The Principle of Reason in the Light of Bosanquet's Philosophy: *Katherine Gilbert.* Bosanquet on Teleology as a Metaphysical Principle: *G. W. Cunningham.* An Estimate of Bosanquet's Philosophy: *J. A. Leighton.* Bosanquet's Theory of the Real Will: *G. H. Sabine.* Bosanquet's Interpretation of Religious Experience: *E. L. Schaub.*

THE JOURNAL OF ABNORMAL PSYCHOLOGY AND SOCIAL PSYCHOLOGY. Volume XVIII, No. 3. Some Mechanisms Which Distinguish the Crowd from other Forms of Social Behavior: *E. D. Martin.* The Influence of Alcohol: *H. L. Hollingworth.* A Case of Complete Loss of All Sensory Functions Excepting Hearing: *Morton Prince.* Motor Speech Functions in Dreams: *W. D. Tait.* Commonplace Mistakes in Psychic Functioning: *S. A. Tannenbaum.* Suggestion as a Form of Medical Magic: *I. H. Coriat.* The Inferiority Reaction: *English Bagby.* In Memoriam—Boris Sidis, An Appreciation: *H. A. Bruce.* Discussion—William McDougall's "Outline of Psychology": *H. N. Gardiner.*

THE JOURNAL OF EDUCATIONAL PSYCHOLOGY. Vol. XIV, No. 9. On the Improvement in Intelligence Scores from Fourteen to Eighteen: *E. L. Thorndike.* The Relative Predictive Values of Certain Intelligence and Educational Tests together with a Study of the Effect of Educational Achievement Upon Intelligence Test Scores: *A. I. Gates* and *J. La Salle.* A study of the Relation between Ability to Learn and Intelligence as Measured by Tests: *O. J. Johnson.* Scales for Measuring Judgment of Orchestral Music: *M. R. Trabue.*

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NOTES AND NEWS

We have received from D. Appleton & Company, New York, a small volume, *A Philosophy of Life and Its Spiritual Values,* by Alfred W. Martin. The book is addressed to that company of readers who in a time of distraction are likely to ask, in Dr. Martin's phrase, the question, "What is human life for?" Addressed to such an audience, and owning some kinship with guides to the perplexed, it is natural that Dr. Martin should exclude from proper answers to his crucial question such pursuits as those of happiness, wealth, health, and culture, and find the key to a satisfying answer in the progressive organization of life "not in enmity to any one

instinct or impulse, but with due regard for all—the ultimate aim being 'health of soul' as Plato called it." Dr. Martin apparently finds the moral life a mystery whose only possible solution is what he calls the "eternality of our spiritual self-hood."

He has a chapter entitled "Is Death the End?" in which he deals with immortality in a manner both suggestive and perplexing. It is perplexing in that it presents us with the possibility of another existence similar to the present in this respect, that it will afford us continued opportunity to complete what we leave uncompleted here. He seems to argue that nature's failures in our brief life can be justified or excused only on the ground that nature will provide another opportunity. This seems to us to be a wholly physical conception of immortality. On the other hand, the chapter is suggestive at the end in trying to lift the conception of immortality out of physical entanglements and make of it a distinctly spiritual achievement quite independent of what might be called continued existence. We suspect that the general tone of the book—the tone of the pilgrim seeking his goal—is largely the result of the initial question with which Dr. Martin starts. Perhaps instead of asking what human life is for—a question perplexing enough in its implications—one might ask, "what opportunities does human life offer?" and be lead to a philosophy of life a little more vigorous and perhaps a little more humane.

The Colver Lectures at Brown University for 1923 were delivered by Dean Charles H. Haskins of Harvard with the title "The Rise of Universities." They are now published by Henry Holt and Company, New York, in an attractive form. Dean Haskins has brought together a great deal of material bearing on the earliest universities, the medieval professor, and the medieval student, and presented it in a most interesting and engaging fashion. He has added a comprehensive bibliographical note to guide the reader who wishes to pursue the matter further. The little book is a most illuminating essay, well calculated to make both the modern university professor and the modern university student conscious both of their differences from the past and also of the great tradition they have inherited.